PHYSICS & TECHNOLOGY

TARGET SKILLS
- **Analyzing and interpreting**
- **Communicating results**

Simulating Microgravity

In preparation for space flights, astronauts benefit by practising movements in microgravity conditions. As you recall from your study of projectile motion, an object will follow a parabolic trajectory if the only force acting on it is gravity. Large jet aircraft can fly on a perfect parabolic path by exerting a force to overcome air friction. Thus, inside the aircraft, all objects move as though they were following a path determined only by gravity. Objects inside the aircraft, including people, exert no forces on each other, because they are all "falling" with the same acceleration. Astronauts can experience 20 s of microgravity on each parabolic trajectory.

Scientists have also found that certain chemical and physical reactions occur in a different way in microgravity. They believe that some manufacturing processes can be carried out more efficiently under these conditions — a concept that might lead to manufacturing in space. To test some of these reactions without going into orbit, researchers sometimes use drop towers, as shown in the photograph. A drop tower has a very long shaft that can be evacuated to eliminate air friction. A sample object or, sometimes, an entire experiment is dropped and the reaction can proceed for up to 10 s in microgravity conditions. These experiments provide critical information for future processing in space.

Analyze

1. Explain in detail why an airplane must use energy to follow an accurate parabolic trajectory, but everything inside the airplane appears to be weightless.
2. Do research to learn about some chemical or physical processes that might be improved by carrying them out in microgravity.

WEB LINK

www.mcgrawhill.ca/links/physics12

To learn more about experiments carried out in drop towers, go to the above Internet site and click on **Web Links**.

Perturbing Orbits

In all of the examples that you have studied to this point, you have considered only perfectly circular or perfectly elliptical orbits. Such perfect orbits would occur only if the central body and satellite were totally isolated from all other objects. Since this is essentially never achieved, all orbits, such as those of planets around the Sun and moons and satellites around planets, are slightly distorted ellipses. For example, when an artificial satellite is between the Moon and Earth, the Moon's gravity pulls in an opposite direction to that of Earth's gravity. When a satellite is on the side of Earth opposite to the Moon, the Moon and Earth exert their forces in the same direction. The overall effect is a very slight change in the satellite's orbit. Engineers must take these effects into account.

In the solar system, each planet exerts a gravitational force on every other planet, so each planet perturbs the orbit of the other planets. In some cases, the effects are so small that they cannot be measured. Astronomers can, however, observe these **perturbations** in the paths of the planets when the conditions are right. In fact, in 1845, two astronomers in two different countries individually observed perturbations in the orbit of the planet Uranus. British astronomer and mathematician John Couch Adams (1819–1892) and French astronomer Urbain John Joseph Le Verrier (1811–1877) could not account for their observed perturbations of the planet's orbit, even by calculating the effects of the gravitational force of the other planets. Both astronomers performed detailed calculations and predicted both the existence and the position of a new, as yet undiscovered planet. In September of 1846, at the Berlin Observatory, astronomer J.G. Galle (1812–1910) searched the skies at the location predicted by the two mathematical astronomers. Having excellent star charts for comparison, Galle almost immediately observed the new planet, which is now called "Neptune."

About 50 years later, U.S. astronomer Percival Lowell (1855–1916) performed calculations on the orbits of both Neptune and Uranus, and discovered that these orbits were again perturbed, probably by yet another undiscovered planet. About 14 years after Lowell's death, astronomer Clyde Tombaugh (1906–1997), working in the Lowell Observatory, discovered the planet now called "Pluto."

Since the discovery of two planets that were predicted mathematically by the perturbations of orbits of known planets, several more predictions about undiscovered planets have been made. None have been discovered and most astronomers believe that no more planets exist in our solar system. The laws of Newton and Kepler, however, have provided scientists and astronomers with a solid foundation on which to explain observations and make predictions about planetary motion, as well as send space probes out to observe all of the planets in our solar system.

3.2 Section Review

1. C Explain Newton's thought experiment about "launching a cannon-ball satellite."
2. I Why must a geostationary satellite orbit over the equator? To answer that question, think about the point that is the centre of the orbit. If you launched a satellite that had a period of 24 hr, but it did not start out over the equator, what path would it follow? If you were at the spot on Earth just below the point where the satellite started to orbit, how would the path of the satellite appear to you?
3. K/U What conditions create apparent weightlessness when an astronaut is in an orbiting spacecraft?
4. K/U How could you discover a planet without seeing it with a telescope?